

UNITED STATES PATENT APPLICATION FOR:

**METHOD AND APPARATUS FOR LOCKING OUT
A SUBSURFACE SAFETY VALVE**

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METHOD AND APPARATUS FOR LOCKING OUT A SUBSURFACE SAFETY VALVE

RELATED APPLICATIONS

[0001] This new application for letters patent claims priority from an earlier-filed provisional patent application entitled "Method and Apparatus for Locking Out a Subsurface Safety Valve." That application was filed on July 12, 2002 and was assigned Application No. 60/395,521.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention is related generally to safety valves. More particularly, this invention pertains to subsurface safety valves deployed in a wellbore for controlling fluid flow through a production tubing string. More particularly still, the present invention relates to a lockout tool for locking out a safety valve into its open position.

Description of the Related Art

[0003] Subsurface Safety Valves (SSVs) are often deployed in hydrocarbon producing wells to shut off production of well fluids in emergency situations. Such SSVs are typically fitted into production tubing in the wellbore, and operate to block the flow of formation fluids upwardly through the production tubing should a failure or hazardous condition occur at the well surface.

[0004] SSVs are designed either to be slickline retrievable, or tubing retrievable. If a safety valve is configured to be slickline/wireline retrievable (WRSSV), it can be easily removed and repaired. If the SSV forms a portion of the well tubing, it is commonly known as "tubing retrievable" (TRSSV). In this instance, the production tubing string must be removed from the well to perform any safety valve repairs.

[0005] The subsurface safety valve has a flapper member or "plate," that is moveable between an open position and a closed position. In this respect, the flapper member is typically pivotally mounted to mate with a hard seat. When the flapper is in its open position, it is held in a position where it pivots away from the hard seat, thereby opening the bore of the production tubing. However, the flapper is biased to its closed position against the seat.

[0006] The flapper of the safety valve is held open during normal production operations. This is done by the application of hydraulic fluid pressure transmitted to an actuating mechanism. A common actuating mechanism is a cylindrical flow tube, which is maintained in a position adjacent the flapper by hydraulic pressure supplied through a control line. The control line resides within the annulus between the production tubing and the well casing. Pressurized hydraulic fluid is delivered from the surface through the control line, and bears against a piston. The piston, in turn, acts against the cylindrical flow tube, which in turn moves across the flapper valve to hold the valve open. When a catastrophic event occurs at the surface, hydraulic pressure is interrupted, causing the cylindrical flow tube to retract, and allowing the safety valve to quickly close. When the safety valve closes, it blocks the flow of production fluids up the tubing. Thus, the SSV provides automatic shutoff of production flow in response to well safety conditions that can be sensed and/or indicated at the surface. Examples of such conditions include a fire on an offshore platform, sabotage to the well at the earth surface, a high/low flow line pressure condition, a high/low flow line temperature condition, and operator override.

[0007] Removal and repair of the tubing retrievable safety valve is costly and time consuming. It is usually advantageous to delay the repair of the TRSSV yet still provide the essential task of providing well safety for operations personnel while producing from the well. To accomplish these objectives, the safety valve is disabled in the open position, or "locked out". This means that the flapper member is pivoted and permanently held in the fully opened position. In normal circumstances, if the well is to be left in production, a WRSSV may be inserted in

the well, often in lockable engagement inside a bore within the locked out tubing retrievable safety valve. Because of the insertion relationship, the WRSSV necessarily has a smaller inside diameter than the TRSSV, thereby reducing the potential hydrocarbon production rate from the well. Locking out the safety valve will not eliminate a need for remediation later, but the lockout and use of the WRSSV will allow the well to stay on production (most often, with a reduced production rate) or perform other work functions in the tubing until the TRSSV can be repaired or replaced.

[0008] Various types of mechanical lockouts have been proposed. Examples are found in U.S. Pat. Nos. 3,696,868; 3,786,865; and 3,786,866. In these applications, various additional parts are necessary to enable the valve to be locked out. Such parts are integral to each and every valve. It is interesting to note that modern SSVs are extraordinarily reliable, and such lockout mechanisms are not used except in a small fraction of the total valve population; yet, integral lockout mechanisms are present in, and add unnecessary cost to, most prior art SSV assemblies. Further, integral lockout mechanisms are not normally operated for extended periods of time, often for years, and are not normally or even periodically actuated. For these reasons, the integral lockout mechanisms may themselves fail to work for various reasons such as sand, corrosion, scale and asphaltine buildup.

[0009] Other inventors have realized the disadvantages of integral lockout mechanisms, and inventions have been disclosed in U.S. Pat. Nos. 4,574,889 (Pringle '889), 4, 577,694 (Brakage, Jr. '694) and 6,059,041 (Scott '041). These inventions recognize a need to remove integral lockout mechanisms and requisite structure from the SSV.

[0010] Pringle '889 teaches a method and apparatus of locking out a subsurface safety valve. The apparatus provides a housing having a bore and one downwardly directed shoulder adjacent the bore. The shoulder makes an outward indentation in the flow tube at a predetermined location whereby the indentation will engage a downwardly directed shoulder in the housing,

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preventing the flow tube from moving to the closed position. The mechanism has the limitation of making only a single indentation during any stroke of the lockout tool. This results in very high localized stresses at the point of impact, causing embrittlement of the material, and possibly undesirably punching through the flow tube. Further, there is no mechanism disclosed to index the punching mechanism to another radial position. Because the SSV assembly is often placed thousands of feet below the earth's surface, using the device taught by Pringle '889 to make second or subsequent indentations in the flow tube in any other radial position is unreliable. Therefore, the operator can only be assured of making a single indentation or, worse, a single penetration of the flow tube. When penetration occurs a metal flap is formed, usually connected by a very small area of metal resembling the infamous "hanging chad" of Florida election lore. A SSV that is locked out in such a manner may not stay locked out when slickline, coiled tubing or other remediation procedures are performed on the well below the SSV. In this respect, when such service tools are pulled up through the locked out SSV, shearing the indentation or flap can occur, resulting in an undesirable unlocking of the valve. Such unlocking can lead to the well again being prematurely shut in, and a resultant loss of production.

[0011] Brakage, Jr. '694 teaches a method and apparatus for permanently locking a shiftable valve member in a well conduit in an open position. The invention provides a spring metal band that is adapted to expand from a contracted, run-in position to a radially enlarged locking position. The band thereby holds the valve member in an open position. The band is deposited in the SSV by a specially adapted slickline tool. While this invention satisfies the need to remove the integral lockout from the safety valve, an additional part, (the spring metal band) is introduced into the SSV assembly downhole. Further, after deposition, the metal band is not positively attached to anything inside the SSV, but is held in place only by the frictional force exerted by the spring metal band. Certain flow regimes in the wellbore can collapse the spring metal band and

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allow it to flow out of the SSV, thereby causing the well to inadvertently shut in.

This phenomenon has been observed.

[0012] Scott' 041 is similar to Brakage Jr. '694 wherein deposition of a radially deflectable blocking member relative to the SSV is provided to enable lockout. In a described embodiment of the apparatus, a lockout tool has mechanisms which effect latching of the tool to an internal profile of a safety valve, displacement of a flow tube of the safety valve to open the safety valve, and deposition of an expandable ring to prevent closure of the safety valve. This invention only partially satisfies the need to remove the integral lockout from the safety valve, because it requires expensive special profiles and again introduces an additional part to enable the lockout. While this is an arguable design improvement over Brakage Jr. '694, certain flow regimes still may flow the radially deflectable blocking member out of the SSV, thereby causing the well to inadvertently shut in.

[0013] There is a need, therefore, for a lockout tool that requires no additional integral SSV parts or expensive special profiles to enable lockout of an SSV. Further, there is a need for a lockout tool that can be deployed by slickline or coiled tubing, and does not attempt to permanently deposit any parts in the safety valve to enable lockout. Still further, there is a need for a lockout tool that does not require special profiles or shoulders in the valve, and can be used to lock out virtually any type of safety valve made by any manufacturer.

SUMMARY

[0014] The present invention is directed to a method and apparatus of locking out a subsurface well safety valve (SSV) in the open position. The SSV itself includes a housing having a bore, a valve closure member in the bore that is movable between an open position and a closed position, a flow tube axially movable in the housing for selectively moving the valve closure member from its closed position to its open position, and an actuator for translating the flow tube longitudinally, e.g., a spring-biased piston.

[0015] The present invention first provides an apparatus that enables a well operator to lock the downhole safety valve into its open position. A lockout tool is provided that is dimensioned to be received within the housing of the safety valve. The lockout tool first comprises a stem. The stem connects the lockout tool to a run-in tool, such as a slickline. The lockout tool also comprises an elongated housing. The housing includes a ball housing portion that houses a plurality of radially disposed balls. Next, the lockout tool comprises an expander mandrel. The expander mandrel is connected to the lower end of the stem by means of a stem extension member. The expander mandrel is received within the housing of the lockout tool.

[0016] A method for "locking out" the safety valve is also provided. In operation, the lockout tool is landed into the housing of an SSV such that the balls are adjacent a non-movable member in the SSV, e.g., the hard seat. The lockout apparatus includes, in one aspect, a set of flow tube dogs and a set of locking dogs. These dogs are disposed intermediate the stem and the housing of the lockout tool. When the stem (and attached expander mandrel) are run into the SSV, the flow tube dogs are landed on top of the flow tube, while the locking dogs are positioned adjacent an internal recess in the SSV housing. As the expander mandrel is urged downward, the locking dogs move radially outward, fixing the lockout tool in the SSV housing. Further movement still of the mandrel extends the flow tube dogs into contact with the flow tube. Still further movement of the mandrel moves the flow tube downward, thereby opening the flapper member.

[0017] The balls in the ball housing are at a depth adjacent the safety valve's hard seat. The expander mandrel is urged further downwardly relative to both the lockout tool housing and the safety valve housing. The expander mandrel includes an enlarged diameter portion. As the expander mandrel is moved downward within the SSV, the enlarged outer diameter portion of the mandrel system engages the balls, forcing them radially outward. The balls, in turn, contact the flow tube and expand the flow tube into permanent, radial and

frictional engagement with the hard seat. The flapper member of the SSV is thereby locked in its open position, preventing the flow tube from returning to the closed position.

[0018] In summary, the method of the present invention in one aspect includes the steps of lowering the lockout tool in a well, locating in the SSV to be locked out, locking the tool in position, moving the flow tube downward thereby opening the flapper member, and from the inside of the bore, outwardly expanding a portion of the flow tube's circumference at a predetermined location whereby the expanded portion firmly engages a non-moveable portion in the housing of the SSV, thereby preventing the flow tube from returning to the closed position. After locking out the safety valve, the lockout tool of the present invention is removed from the well. A result of the expansion operation is engagement between the expanded portion of the flow tube and the non-moveable parts in the safety valve, thereby causing a very high friction force therebetween. The expansion force may also slightly expand the non-moveable metallic parts behind the flow tube, thereby forming an in-situ locking profile. This locking profile engages the expanded portion of the flow tube, further inhibiting the flow tube and the valve from moving to the closed position.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] So that the manner in which the above-recited features of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the appended drawings. In some instances, moving parts are shown in solid black for ease of reference. It is to be noted that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0020] Figure 1 presents a side elevational view of a permanent lockout tool of the present invention, in one embodiment. The lockout tool is shown in its run-in position.

[0021] Figure 2 is a side view of the lockout tool of Figure 1, in cross-section. More visible in this view are two expander balls at the lower end of the tool. The lockout tool is designed to be mechanically activated.

[0022] Figure 3A presents a cross-sectional view of the permanent lockout tool of Figure 2. In this view, the lockout tool has been landed within a subsurface safety valve. It can be seen that a lower end prong of the tool has contacted the flapper within the valve assembly, forcing the flapper to open.

[0023] Figure 3B is a cross-sectional view of the lockout tool of Figure 3A, taken across line B-B of Figure 3A. More visible in this view are three carrier sleeve locking dogs pushing outward against an upper housing of the lockout tool. The three carrier sleeve locking dogs are supported by slots machined into the stem extension member.

[0024] Figure 3C is a cross-sectional view of the lock out tool of Figure 3A. Here, the view is taken across line C-C of Figure 3A. Seen more readily in this view are flow tube dogs and locking dogs radially disbursed around the stem extension, and carried by a carrier sleeve.

[0025] Figure 3D provides a cross-sectional view of the lockout tool of Figure 3A, taken across line D-D of Figure 3A. Visible in this view are carrier sleeve no-go dogs disposed within the housing, and around an expander mandrel. The carrier sleeve no-go dogs are carried by a carrier sleeve.

[0026] Next, Figure 3E provides a cross-sectional view through line E-E of Figure 3A. Visible in this view are a plurality of radially disposed expander balls within a ball housing. The balls are arranged around the expander mandrel. A surrounding string of production tubing is seen.

[0027] Figure 4A presents a side elevational view, in cross-section, of the permanent lockout tool of the present invention. In this view, the stem and stem

extension members are beginning to be pushed downward into the lockout tool. A shear pin supporting the upper stem has been sheared.

[0028] Figure 4B shows a cross-sectional view of the lockout tool of Figure 4A, taken across line B-B of Figure 4A. Visible again in this view are three carrier sleeve locking dogs pushing outward against the upper housing. The three carrier sleeve locking dogs remain supported by the slots machined into the stem extension member.

[0029] Figure 4C provides a cross-sectional view of the lockout tool of Figure 4A. The cut is taken across line C-C. The flow tube dogs and locking dogs are again shown disposed around the stem extension. The locking dogs have not yet backed outwardly, but remain adjacent the stem extension.

[0030] Figure 4D shows a cross-sectional view of the lockout tool of Figure 4A, taken across line D-D. In the view, both the stem extension member and the expander mandrel are seen within the carrier sleeve no-go dogs.

[0031] Figure 4E gives a cross-sectional view of the lockout tool of Figure 4A, cut through line E-E. There is no change in the relative position of the expander balls as compared to Figure 3E. In this regard, the expander balls remain fully retracted.

[0032] Figure 5A presents the lockout tool, again in cross-section. In this view, the stem continues to be driven downward into the lock out tool. The locking dogs have now popped outwardly from the stem extension, and have engaged a profile in the safety valve housing.

[0033] Figure 5B provides a cross-sectional view of the tool of Figure 5A, taken across line B-B. There is no relative change in position of the carrier sleeve locking dogs from the view of Figure 4B.

[0034] Figure 5C shows the lockout tool of Figure 5A, in cross-section. The view is taken across line C-C. In this view, it can be seen that the locking dogs have popped outwardly into the profile of the valve housing.

[0035] Figure 5D is a cross-sectional view of the lock out tool of Figure 5A. Here, the view is taken across line D-D of Figure 5A. There has been no relative movement of the carrier sleeve no-go dogs in this view as compared to Figure 4D. Both the stem extension and the expander mandrel are seen within the carrier sleeve no-go dogs.

[0036] Figure 5E creates a cross-sectional view of the tool of Figure 5A, taken across line E-E, and showing again the plurality of expander balls. There is again no change in the relative position of the expander balls as compared to Figure 3E.

[0037] Figure 6A is a cross-sectional view of the lockout tool of Figure 5A, and shows the next step in the tool actuation process. The stem continues to be driven downward into the lockout tool. In this view, the flow tube dogs have also popped outwardly into the recess in the valve housing. This enables the flow tube dogs to also clear a shoulder in an upper housing.

[0038] Figure 6B presents a cross-sectional view of the tool of Figure 6A. The view is taken across line B-B of Figure 6A. There is no relative change in position of the carrier sleeve locking dogs from Figure 5B.

[0039] Figure 6C demonstrates another cross-sectional view of the tool of Figure 6A, taken across line C-C. In this view, it can be seen that both the flow tube dogs and the locking dogs have expanded outwardly relative to the stem extension.

[0040] Figure 6D shows a cross-sectional view of the lockout tool of Figure 6A. The cut is through line D-D of Figure 6A. The carrier sleeve no-go dogs are again seen disposed within the flapper valve housing, and around the stem extension member. However, the expander mandrel is no longer seen, as it has been urged below line D-D.

[0041] Figure 6E creates a cross-sectional view of the tool of Figure 6A, taken across line E-E. There is still no change in the relative position of the expander

balls as compared to Figure 3E, meaning that the expander balls remain retracted.

[0042] Figure 7A is a side elevational view, in cross-section, of the permanent lockout tool of the present invention, presenting the next step in the tool actuation process. In this view, the stem continues to be driven still further into the lockout tool. This has enabled the carrier sleeve locking dogs to clear an enlarged outer diameter portion of the stem extension member. A lower shoulder in the stem extension member has now engaged the no-go dogs.

[0043] Figure 7B provides a cross-sectional view of the tool of Figure 7A, taken across line B-B of Figure 7A. It can be seen that the carrier sleeve locking dogs have been able to move inwardly due to the reduced outer diameters of the slots in the stem extension.

[0044] Figure 7C shows a cross-sectional view of the tool of Figure 7A. Here, the view is taken across line C-C. Visible again in this view are flow tube dogs and locking dogs radially disposed around the stem extension member. It can be seen that the outer diameter of the stem extension is enlarged relative to the cross-sectional view of Figure 6C.

[0045] Figure 7D creates a cross-sectional view of the lockout tool of Figure 7A, with the view cut across line D-D. A lower shoulder below the enlarged outer diameter portion of the stem extension member has engaged the carrier sleeve no-go dogs. This allows the stem extension member to push downwardly on the carrier sleeve no-go dogs and attached carrier sleeve.

[0046] Next, Figure 7E provides a cross-sectional view through line E-E. There is yet no change in the relative position of the expander balls as compared to Figure 3E.

[0047] Figure 8A presents yet another cross-sectional view of the tool of the present invention, in one embodiment. The next step in the tool actuation step is presented. In this view, the stem continues to be driven downward into the lockout tool. The flow tube dogs have extended further outwardly in order to

shoulder against the top of the flow tube in the safety valve. As the stem is driven downward, it will drive the flow tube downwardly.

[0048] Figure 8B provides a cross-sectional view of the tool of Figure 8A, with the view taken across line B-B. Three carrier sleeve locking dogs are again visible adjacent the carrier sleeve. The diameters of the slots in the stem extension is now reduced.

[0049] Figure 8C shows a cross-sectional view of the lock out tool of Figure 8A, cut across line C-C. The flow tube dogs and locking dogs are seen radially disbursed about the carrier sleeve. The flow tube dogs are fully expanded outwardly against the inner diameter of the safety valve housing, and are in position to exert downward force against the flow tube.

[0050] Figure 8D gives a cross-sectional view of the lock out tool of Figure 8A, shown through line D-D of Figure 8A. The carrier sleeve no-go dogs are seen riding with the carrier sleeve.

[0051] Figure 8E shows a cross-sectional view of the tool of Figure 8A, taken across line E-E. There remains no visible change in the relative position of the expander balls as compared to Figure 3E.

[0052] Figure 9A presents a cross-sectional view of the permanent lockout tool of Figure 8A. In this view, the stem continues to be driven downward into the housing of the tool. The carrier sleeve and connected flow tube dogs are seen driving the flow tube downward. Also, the stem extension member is driving the carrier sleeve no-go dogs and connected carrier sleeve downward.

[0053] Figure 9B provides a cross-sectional view of the tool of Figure 9A. The view is taken across line B-B of Figure 9A. The locking dogs are now seen adjacent the carrier sleeve locking dogs around the carrier sleeve.

[0054] Figure 9C is a cross-sectional view of the lock out tool of Figure 9A, taken across line C-C of Figure 9A. The flow tube dogs are fully expanded outwardly against the inner diameter of the safety valve housing, and are in position to exert downward force against the flow tube.

[0055] Figure 9D is a cross-sectional view of the lock out tool of Figure 9A, taken across line D-D of Figure 9A. Visible in this view are carrier sleeve no-go dogs disposed within the flapper valve housing, and around the expander mandrel. The carrier sleeve no-go dogs continue to be driven downward by the stem extension member.

[0056] Figure 9E creates a cross-sectional view of the lockout tool of Figure 9A, taken across line E-E. There remains no change in the relative position of the expander balls as compared to Figure 3E such that the expander balls remain retracted. However, the flow tube is now visible adjacent the balls.

[0057] Figure 10A presents the next step in the actuation process for the lockout tool after the step of Figure 9A. Figure 10A is another cross-sectional view of the lockout tool. In this view, the stem and connected stem extension member have been driven further downward into the housing for the safety valve. The flow tube dogs have now moved the flow tube to the end of its downward stroke. The flapper valve is fully opened by the flow tube.

[0058] Figure 10B provides a cross-sectional view of the lockout tool of Figure 10A, taken across line B-B. The carrier sleeve locking dogs continue to move downward through the safety valve housing with the stem and the carrier sleeve.

[0059] Figure 10C shows a cross-sectional view of the tool, with the view being taken through line C-C. The flow tube dogs are again visible, and remain fully expanded outwardly against the inner diameter of the safety valve housing.

[0060] Figure 10D demonstrates a cross-sectional view of the lockout tool, cut through line D-D of Figure 10A. The carrier sleeve no-go dogs continue to be driven downward by the lower shoulder in the stem extension member.

[0061] Figure 10E shows the lockout tool of Figure 10A, in cross-section. The view is taken across line E-E. There is again no change in the position of the expander balls relative to the flow tube of the safety valve as compared to Figure 3E. The flow tube remains visible circumferentially around the ball housing keeping the flapper in its fully open position.

[0062] Figure 11A is a cross-sectional view of the lockout tool, in its next step of tool actuation. In this view, the stem is moving still further downward into the safety valve. The connected stem extension member is now moving downwardly inside the flow tube. In addition, the carrier sleeve no-go dogs have popped outwardly into a recess in the upper housing, allowing the stem extension to also move downwardly relative to the carrier sleeve and connected no-go dogs. Most importantly, an enlarged diameter portion of the expander mandrel is now contacting the expander balls.

[0063] Figure 11B provides a cross-sectional view of the lockout tool of Figure 11A, taken across line B-B. The position of the carrier sleeve locking dogs relative to the upper housing has not changed from the view of Figure 10B.

[0064] Figure 11C shows the lockout tool of Figure 11A, in cross-section. The view is taken across line C-C. There is also no change in the position of the flow tube dogs relative to the tool housing.

[0065] Figure 11D gives another cross-sectional view of the tool of Figure 11A. Here, the view is taken across line D-D. The carrier sleeve no-go dogs, which have been urged outwardly into a recess in the housing, are adjacent the enlarged diameter portion of the stem extension member.

[0066] Next, Figure 11E provides a cross-sectional view through line E-E. The plurality of expander balls is again seen. It can be seen that the diameter of the expander mandrel has been enlarged relative to the diameter shown in previous "E-E" cross-section views. This causes the expander balls to be urged outwardly against the flow tube.

[0067] Figure 12A presents a cross-sectional view of the lockout tool of Figure 11A. Figure 12A provides the final step in the lockout process. In this view, it can be seen that the expander mandrel has been driven through the flapper of the safety valve. The expander balls and flow tube dogs have retracted, allowing the tool to be later removed from the wellbore with tension placed in the slickline (or other working string).

[0068] Figure 12B is a cross-sectional view of the tool of Figure 12A, taken across line B-B. The stem extension member has been moved through the tool housing to the extent that the upper end of the stem extension member is adjacent the locking dogs.

[0069] Figure 12C provides a cross-sectional view taken across line C-C of Figure 12A. It can be seen that the flow tube dogs have cleared the enlarged diameter portion of the stem extension. The flow tube dogs are recessing inward to a reduced diameter cut in the stem extension.

[0070] Figure 12D shows the tool of Figure 12A in cross-section, with the view being taken across line D-D. The carrier sleeve no-go dogs slideably receive the stem extension member.

[0071] Figure 12E shows the lockout tool, in cross-section. The view is taken across line E-E of Figure 12A. The expander balls have retracted and are no longer acting against the radial dimension of the flow tube.

[0072] Figure 13 presents a cross-sectional view of an alternate embodiment of the lockout tool of the present invention. In this arrangement, a grooved and spiraled spline is placed around the expander mandrel at the level of the enlarged diameter portion.

[0073] Figure 14 presents a perspective view of an expander point that might be used in lieu of an expander ball. The expander point of this figure is a dog. A plurality of radially disbursed dogs would be deployed around the ball housing where the dogs are used.

[0074] **Figure 15** shows an alternate embodiment for the lockout tool **100** of **Figure 1**. In this embodiment, the lockout tool is hydraulically activated. The lockout tool is seen in a side, cross-sectional view.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

[0075] **Figure 1** presents a perspective view of a lockout tool **100** of the present invention, in one embodiment. In this view, the lockout tool **100** is shown

in its run-in position. The lockout tool **100** is designed to be landed within a tool **50** to be expanded within a hydrocarbon wellbore (not shown in **FIG. 1**). An example of such a tool is a subsurface safety valve **50** (also not shown in **FIG. 1**).

[0076] The present invention will be described in connection with a tubing retrievable surface controlled subsurface flapper type safety valve. It will be understood, however that the present invention may be used with other types of subsurface safety valves, including those having different type valve closure members such as balls, and those having different type actuation methods, such as subsurface controlled (i.e., velocity, dome charged, and injection) safety valves. In addition, and as will be described in further detail below, the lockout tool may be used to radially expand a selected portion of any tubular into engagement with a surrounding second tubular within a wellbore.

[0077] Regardless of the type, the subsurface safety valve **50** ("SSV") will have certain standard features (seen in **Figure 3A**). First, the valve **50** will have a pressure containing body **52**. This body **52** typically defines an elongated tubular housing having a bore **55** therethrough. The valve **50** will also have a moveable flow tube **54** disposed within the housing **52**. The flow tube **54** moves along the longitudinal axis of the housing **52** in order to selectively open and close a valve closure member **60**. The valve closure member **60** is commonly referred to as a "flapper plate," or just "flapper."

[0078] The flapper **60** is pivotally mounted onto a non-moveable element such as a hard seat **58**. The hard seat **58** is mounted within the housing **52**, typically below the flow tube **54**. The hard seat **58** defines a short tube or ring that is dimensioned to receive the flow tube **54** when the flapper **60** moves to its closed position.

[0079] The flow tube **54** is biased in a position that is retracted from the hard seat **58**. Likewise, the flapper **60** is biased in its closed position against the hard seat **58**. The biasing force is typically provided by a powerful spring (not shown). It is only when the biasing force acting against the flow tube **54** is overcome, that

the flow tube **54** can move through the hard seat **58** and open the flapper **60**. However, where the SSV **50** malfunctions and the flow tube **54** cannot move through the hard seat **58** in order to urge the flapper **60** open, the lockout tool **100** is employed. Thus, the present invention provides an apparatus for moving the flow tube **54** downward through the hard seat **58**, and holding the flapper **60** in its open position. The present invention also provides a method for engaging and mechanically moving the flow tube **54** through the hard seat **58**, and then expanding the flow tube **54** into permanent frictional engagement with the surrounding hard seat **58**. In this way, the flow tube **54** is locked into a position holding the flapper member **60** permanently in the open position.

[0080] Referring again to **Figure 1**, the lockout tool **100** generally comprises first an elongated stem **110**. In one arrangement, the stem **110** defines an upper stem portion **112**, and an upper stem extension portion **114**, or "stem extension portion." The separate upper stem **112** and upper stem extension **114** portions are seen in **Figure 2**. The stem **110** has a top end **102** designed to be connected to a run-in tool, such as a wire line apparatus (not shown). Alternatively, the stem **110** may be deployed at the end of a string of coiled tubing (also not shown).

[0081] The lockout tool **100** next comprises a housing **120**. In one arrangement, the housing **120** comprises several tubular portions, including a no-go housing **130**, an upper housing extension **152**, an upper housing **150** and a ball housing **160**. These separate housing portions are also shown in **Figure 2**. The no go housing **130**, upper housing extension **152**, upper housing **150**, and ball housing **160** together form a single elongated housing **120** configured to receive the stem **110** when the lockout tool **100** is actuated. The use of separate housings **130**, **150**, **160** assist in assembly of the tool **100**.

[0082] In the perspective view of **Figure 1**, a slot **153** can be seen in the upper housing **150**. Preferably, three elongated slots are radially disposed around the upper housing **150**. As will be described more fully below, each of the elongated slots **153** receives a flow tube dog **186**. The flow tube dogs **186**

engage the flow tube **64** of the safety valve **50** in order to drive it downward, thereby placing the flapper **60** in its open position.

[0083] Disposed within the housing **120** are a plurality of expander points **105**. The expander points **105** in one arrangement are radially disposed within the ball housing **160** at a lower end of the lockout tool **100**. In the arrangement described below in connection with **Figures 4A** through **12A**, the expander points **105** define radially disbursed balls. The balls **105** are preferably fabricated from a hardened material, such as carbide. As will be shown, the expander balls **105** are urged radially outward against the flow tube **54** (or other tubular to be expanded) in order to "lock" the flapper **60** of the safety valve **50** into its open position. However, it is understood that the expander points **105** may define any outwardly movable protrusion, such as a plurality of hammers, e.g., shaped dogs, placed in an array. **Figure 14** presents a perspective view of an individual hammer **105'**.

[0084] The lockout tool **100** next comprises an expander mandrel **170**. The expander mandrel **170** is connected to a bottom end of the stem extension member **114** within the housing **120**. The expander mandrel **170** is urged downwardly relative to the lockout tool housing **120** as the stem **110** is received within the safety valve housing **52**. As more fully shown in the cross-sectional view of **Figure 2**, the expander mandrel **170** is dimensioned to have a varying diameter, including an enlarged diameter portion **176**. As the expander mandrel **170** is urged downwardly within the housing **120**, the expander balls **105** are forced to ride outwardly against the diameter **176** of the expander mandrel **170**. This causes the balls **105** to expand the flow tube **54** in order to lock the flapper member **60** into its open position. More specifically, the expander balls **105** expand the flow tube **54** of the safety valve **50** into frictional engagement with a surrounding non-movable member, such as the hard seat **58**.

[0085] Finally, the lockout tool **100** comprises a lower end prong **104**. The prong **104** extends through a lower opening in the housing **120**, and extends below the housing **120**. The lower end prong **104** is used to contact the flapper

member **60** in the safety valve **50** as the lockout tool **100** is lowered within the wellbore. In one aspect, the outer diameter of the prong **104** is greater than the inner diameter of the lockout tool housing **120**, thereby preventing the expander mandrel **170** from retreating back within the housing **120** upon pullout.

[0086] Referring again to **Figure 2**, **Figure 2** presents a cross-sectional view of the lockout tool **100** of **Figure 1**. Additional details of the lockout tool **100** are seen. First, the upper stem portion **112** is seen. In one arrangement, the upper stem portion **112** defines an elongated solid metal body. In one aspect, the upper stem **112** is a part of a wire line stem used in connection with oil field jars, such as spang jars. The jars are used to hammer downwardly upon a tool within the wellbore by alternately raising the slickline and a connected weighted wire line stem, and dropping the wire line and connected weighted wire line stem upon a steel bar. Thus, the upper stem **112** in the lockout tool **100** may be the steel bar within a set of oilfield jars.

[0087] Connected at the lower end of the stem **110** is the stem extension portion **114**. In the arrangement of **Figure 2**, the stem extension portion **114** also defines an elongated metal shaft. The stem extension **114** has a diameter dimensioned to be slideably received within the housing **120** of the lockout tool **100**. Downward force against the stem **110** causes the stem extension member **114** to move downward within (or relative to) the housing **120** of the lockout tool **100**.

[0088] As noted, the lockout tool **100** also comprises a housing **120**. As shown in **Figure 2**, the housing **120** defines an elongated tubular body. The housing **120** is divided, in one aspect, into several separate portions. First, the housing comprises a no-go housing **130** at an upper end. The no-go housing **130** has an inner diameter dimensioned to receive the upper stem **112** and the stem extension **114** portions of the stem **110**. The no-go housing **130** is connected to the stem **110** via a temporary mechanical connection **140**. In the arrangement of **Figure 2**, the temporary mechanical connection **140** defines one or more shear pins. Sufficient downward force on the upper stem **112** will cause

the shear pin **140** to shear, thereby releasing the upper stem **112** from the no-go housing **130**.

[0089] A top cap **142** is optionally placed above the no-go housing **130** in order to provide further support for the temporary mechanical connection **140**. The top cap **142** has a stem channel **143** that assists in guiding the stem **110** as it slides within the no-go housing **130**. An optional lock ring **146** and lock ring spacer **147** are also provided below the top cap **142**. The lock ring **146** prevents the upper stem **112** from backing out of the no-go housing **130** due to compression of the power spring (not shown) in the SSV **50** during the tool actuation process.

[0090] Optional vents **139** are provided within the no-go housing **130**. The vents **139** provide fluid communication between the inner and outer diameter surfaces of the no-go housing **130** during the tool actuation process. This, in turn, further enables the upper stem **112** to move downwardly relative to the housing **120**, and to displace any fluid found within the inner diameter of the no-go housing **130**, and other housing portions, e.g., upper housing **150**.

[0091] The housing **120** next comprises an upper housing **150**. The upper housing **150** likewise defines an elongated tubular body. The upper housing **150** is disposed below the no-go housing **130**. The upper housing **150** includes an inwardly facing shoulder **151** having upper and lower shoulder surfaces. Optional vents **159** are provided within the upper housing **150**.

[0092] In the arrangement of **Figure 2**, an upper housing extension **152** is disposed intermediate the no-go housing **130** and the upper housing **150**. An upper end of the upper housing extension **152** is threadedly connected to the no-go housing **130**. Similarly, a lower end of the upper housing extension **152** is threadedly connected to the upper housing **150**. A separate set of vents **157** is optionally placed within the upper housing extension **152**.

[0093] Finally, the housing **120** comprises a ball-housing portion **160**. The ball housing **160** also defines an elongated tubular member. An upper end of the

ball housing **160** is, in one aspect, threadedly connected to a lower end of the upper housing **150**. Vents **169** are seen disposed in the ball housing **160**. In its lower end, the ball housing **160** includes a recess **166** for receiving a plurality of expander balls **105**. As noted, and as will be explained in greater detail below, the expander balls **105** are urged radially outward against the non-moveable element **58** of the safety valve **50** when the lockout tool **100** is actuated.

[0094] As noted, the lockout tool **100** of **Figure 1** and **Figure 2** next comprises an expander mandrel **170**. The expander mandrel **170** has an upper end **172** and a bottom end **174**. The upper end **172** of the expander mandrel **170** is connected to a lower end of the stem extension member **114**. The lower end **174** of the expander mandrel **170**, in turn, extends proximate to the lower end of the ball housing **160**. The lower end **174** of the expander mandrel **170** includes a lower end prong **104** that extends below the ball housing **160**. In one aspect, the lower end prong **104** is a separate piece threadedly connected to the lower end **174** of the expander mandrel **170**. In the particular arrangement shown in **Figure 2**, and as noted above, the lower end prong **104** has an outer diameter that is greater than the inner diameter of the ball housing **160**. This further helps to keep the stem **110** (including the stem extension **114**) and inner mandrel **170** from retracting upward relative to the lockout tool housing **120**, especially during pullout.

[0095] In order to enable and assist the movement of the stem **110** and the inner mandrel **170** within the housing **120**, various dogs are employed. These preferably include (1) at least one carrier sleeve locking dog **182**; (2) at least one locking dog **184**; (3) at least one flow tube dog **186**; and (4) at least one carrier sleeve no-go dog **188**. Those of ordinary skill in the general art of designing wellbore tools will understand that dogs are utilized to provide releasable connections between tubular members. Dogs may be biased inward or outward in order to selectively achieve relative movement between tubular members upon release. Alternatively, dogs may not be biased, but are urged to move in response to forces from adjacent tubular members.

[0096] The dogs **182, 184, 186, 188** of the present invention are carried along by a sleeve **180**. The carrier sleeve locking dog **182**, the flow tube dog **186** and the carrier sleeve no-go dog **188** are connected via a carrier sleeve **180**, while the locking dog **184** resides adjacent the carrier sleeve **180**. The relative functions of the carrier sleeve locking dogs **182**, the locking dogs **184**, the flow tube dogs **186** and the carrier sleeve no-go dogs **188** should be noted here. The carrier sleeve locking dogs **182** serve to prevent the carrier sleeve **180** from moving before a lower shoulder **119** of the upper stem extension **114** contacts the carrier sleeve no-go dogs **188**. The locking dogs **184** serve to maintain the position of the lockout tool **100** within the safety valve **50** during the lockout process. The flow tube dogs **186** land on top of the flow tube **54** and drive the flow tube **54** downward. Finally, the carrier sleeve no-go dogs **188** shift the carrier sleeve **180** downward when contacted by the lower shoulder **119** of the upper stem extension **114**.

[0097] The precise functions of the various dogs are more fully understood in light of the cross-sectional views of **Figures 3A-12A**, discussed below. More specifically, **Figures 3A-12A** provide a step-by-step presentation for actuation of the lockout tool **100**. It should again be noted that certain parts in the drawings are sometimes darkened. This indicates that the part is either moving, or is about to be moved.

[0098] **Figure 3A** presents a cross-sectional view of a lockout tool **100** of the present invention, in one arrangement. In this view, the lockout tool **100** has been landed in a subsurface safety valve **50**. The SSV **50** itself includes a housing **52**, a bore **55** within the housing, a non-moveable element **58** (such as a hard seat) and a valve closure member **60**, i.e. "flapper" pivotally mounted onto the hard seat **58**. The flapper **60** resides within the bore **55**, and is movable between an opened position and closed position. The safety valve **50** also includes a flow tube **54** axially moveable within the bore **55** of the housing **52** for controlling the movement of the flapper **60**, and an actuator, e.g., piston **57**, for translating the flow tube **54** longitudinally. Certain features of a typical SSV **50**,

such as the hydraulic flow line and a spring biasing the flow tube **54** upwardly, are not shown. More details concerning features of the safety valve itself, in one arrangement, are described in U.S. Patent Application Serial No. 09/998,800. Named inventors on that pending application are Deaton and Jancha.

[0099] As shown in **Figure 3A**, the lockout tool **100** has been lowered into the safety valve **50** to a depth such that the lower end prong **104** has contacted the flapper **60**. Further, the lower end prong **104** has forced the flapper **60** partially open. The injection of fluid at a rate sufficient to equalize the pressure above and below the flapper **60** within the wellbore may be provided to aid in opening the flapper **60**. In one arrangement, the lockout tool **100** may be lowered into the wellbore using coiled tubing in lieu of a wire line tool, with pressure being injected into the wellbore through the coiled tubing.

[00100] In order to properly land the lockout tool **100** into the flapper valve **50**, a locating shoulder **136** is fabricated into the outer diameter of the no-go housing **130**. The locator shoulder **136** matches a beveled shoulder provided in a typical subsurface safety valve **50**. In this manner, the lockout tool **100** may be dropped to the appropriate position within the safety valve **50** in order to conduct the expansion operation of the present invention. More specifically, the expander balls **105** are located at a depth that parallels the location of the non-moveable member, e.g., hard seat **58** of the safety valve **50**. In the view of **Figure 3A**, the expander balls **105** are located adjacent the hard seat **58** immediately above the flapper **60**.

[00101] In the position of the lockout tool **100** in **Figure 3A**, a downward force has not yet been applied against the stem **110**. It can be seen that the shear pin **140** has not yet been broken. Thus, the upper **112** and lower **114** stem members and inner mandrel **170** are held in place relative to the lockout tool housing **120**. It can also be seen that the carrier sleeve locking dog **182**, the locking dog **184**, the flow tube dog **186** and the carrier sleeve no-go dog **188** are each in their run-in position, in accordance with **Figure 2**.

[00102] **Figure 3B** is a cross-sectional view of the lockout tool **100** of **Figure 3A**. The tool **100** is landed within the valve housing **52**. The view of **FIG. 3B** is taken across **line B-B**. More visible in this view are three carrier sleeve locking dogs **182** disposed within the upper housing **150**. The three carrier sleeve locking dogs **182** are supported by slots **115** machined into the stem extension **114**. The stem extension **114** is seen within the carrier sleeve locking dogs **182**.

[00103] **Figure 3C** presents a cross-sectional view of the lockout tool of **Figure 3A**, taken across **line C-C** of **FIG. 3**. **Line C-C** is just below **line B-B**, and is cut across the flow tube dogs **186** and the locking dogs **184**. Visible in this view are both flow tube dogs **186** and locking dogs **184** radially disbursed around the stem extension **114**, and carried by the carrier sleeve **180**. A hydraulic chamber **56** is seen in the valve housing **52**. A piston **57** is seen within the hydraulic chamber **56**.

[00104] **Figure 3D** provides a cross-sectional view of the lockout tool of **Figure 3A**, with the view taken across **line D-D** of **Figure 3A**. **Line D-D** is just below **line C-C**, and is cut across the no-go dogs **188**. In this view, the carrier sleeve no-go dogs **188** are seen disposed within the upper housing **52** and the flow tube **54**, and around the expander mandrel **170**. The no-go dogs **188** are carried by the carrier sleeve **180**.

[00105] Finally, **Figure 3E** shows another a cross-sectional view, taken across **line E-E** of **FIG. 3**. **Line E-E** is cut across the lower end **174** of the expander mandrel **170**. Visible in this view are the plurality of expander balls **105** radially disbursed around the expander mandrel **170**. In this arrangement, six balls **105** are provided, though more or less may be employed. The balls **105** reside within recesses **166** in the ball housing **160**. A surrounding string of production tubing **70** is seen. However, the flow tube **54** is not seen, as it has not yet been driven downwardly.

[00106] Moving now to **Figure 4A**, **Figure 4A** presents a cross-sectional view of the lockout tool **100** of **Figure 3A**. In this view, the lower stem **114** is

beginning to be pushed downward into the valve housing **52**. As noted, the stem **110** may be urged downward by mechanical forces applied through spang jars. Alternatively, hydraulic pressure provided through a working string such as coiled tubing (not shown) may act against the stem. The shear pin **140** supporting the upper stem **112** has been sheared. Downward movement of the upper stem **112**, in turn, exerts downward force against the lower stem **114**. It can also be seen that a lower shoulder **119** in the stem extension **114** is acting downwardly against the locking dogs **184**. Further downward movement will cause the locking dogs **184** to move out into a recess **53** within the valve housing **52**.

[00107] **Figure 4B** is a cross-sectional view of the lockout tool of **Figure 4A**. The view is taken across **line B-B** of **Figure 4A**. Visible again in this view are the three carrier sleeve locking dogs **182** pushing outwardly against the upper housing **150**. The locking dogs **182** remain disposed around the stem **114**, carried by the carrier sleeve **180**.

[00108] **Figure 4C** presents a cross-sectional view of the lockout tool of **FIG. 4**, taken across **line C-C**. Visible again are the flow tube dogs **186** and locking dogs **184** radially disbursed around the stem extension member **114**, and carried by the carrier sleeve **180**. The flow tube dogs **186** and locking dogs **184** are darkened to indicate downward movement. The locking dogs **184** have not yet backed outwardly, but remain adjacent the stem extension **114**.

[00109] **Figure 4D** provides a cross-sectional view of the lockout tool **100** of **Figure 4A**, shown across **line D-D** of the figure. Visible again in this **D-D** view are carrier sleeve no-go dogs **188** disposed within the valve's hard seat **58**, and around the expander mandrel **170**. In the view, both the stem extension member **114** and the expander mandrel **170** are seen within the carrier sleeve no-go dogs **188**. The no-go dogs **188** are retained in this step by the upper housing **150**. The flow tube **54** is seen around the upper housing **150**.

[00110] Finally, **Figure 4E** shows a cross-sectional view of the lockout tool of **Figure 4A**, taken across **line E-E**. The plurality of expander balls **105** are again

seen around the expander mandrel **170**. There is no change in the relative position of the expander balls **105** as compared to **Figure 3E**. In this regard, the expander balls **105** remain retracted against the smaller diameter of the expander mandrel **170** at its lower end **174**.

[00111] Moving to the next step in the tool actuation process, **Figure 5A** presents the lockout tool **100** of **Figure 4A**, again in cross-section. In this view, the stem **110** continues to be driven downward into the lockout tool **100**. This allows the locking dogs **182** to clear both the lower shoulder **119** in the stem extension member **114** and the shoulder **151** in the upper housing **150** as the stem **110** is driven further downward. The locking dogs **182** have now been urged outwardly along the stem extension member **114**, and have engaged the profile **53** in the safety valve housing **52**.

[00112] **Figure 5B** presents a cross-sectional view of the lockout tool **100** of **Figure 5A**. The view is taken across line **B-B** of **Figure 5A**. The three carrier sleeve locking dogs **182** are again seen pushing outwardly towards the upper housing **150**. There is no relative change in the position of the carrier sleeve locking dogs **182** as compared to **Figure 4B**.

[00113] **Figure 5C** provides a cross-sectional view of the lockout tool **100** of **Figure 5A**, with the view taken across line **C-C**. Seen in this view again are the flow tube dogs **186** and the locking dogs **184** radially disposed around the stem extension member **114**, and carried by the carrier sleeve **180**. It can be seen that the locking dogs **184** have popped outwardly into the profile **53** of the valve housing **52**.

[00114] **Figure 5D** demonstrates a cross-sectional view of the lockout tool **100** of **Figure 5A**, taken across line **D-D** of **Figure 5A**. The carrier sleeve no-go dogs **188** are again shown disposed within the valve housing **52**. Both the stem extension member **114** and the upper end **172** of the expander mandrel **170** are again seen within the carrier sleeve no-go dogs **188**.

[00115] Finally, **Figure 5E** shows a cross-sectional view of the lockout tool **100** of **Figure 5A**, cut through **line E-E** of **Figure 5A**. The plurality of radially disbursed expander balls **105** are again shown. There is no change in the radial position of the expander balls **105** as compared to **Figures 3E** and **4E**.

[00116] The next step in the tool actuation process is presented in **Figure 6A**. **Figure 6A** presents a cross-sectional view of the lockout tool **100** of **Figure 5A**. The stem extension member **114** continues to be driven downward into the lockout tool **100**. In this view, the flow tube dogs **186** have also moved outwardly into the recess **53** in the valve housing **52**. This enables the flow tube dogs **186** to be positioned above the piston **54**.

[00117] **Figure 6B** provides a cross-sectional view of the lockout tool **100** of **Figure 6A**. The view is taken across **line B-B** of **Figure 6A**. Again visible are three carrier sleeve locking dogs **182** pushing outward against the upper housing **150**. There is no relative change in position of the carrier sleeve locking dogs **182** as compared to **Figure 5B**.

[00118] **Figure 6C** demonstrates a cross-sectional view of the lockout tool **100** of **Figure 6A**, cut through **line C-C**. In this view, it can be seen that both the flow tube dogs **186** and the locking dogs **184** have expanded outwardly relative to the stem extension member **114**. The flow tube dogs **186** and locking dogs **184** extend into the recess **53** of the valve housing **52**.

[00119] **Figure 6D** shows a cross-sectional view of the lockout tool **100** of **Figure 6A**, taken across **line D-D**. Visible now in the center of this view is the lower stem **114**, partially in cross-section, and partially looking at the bottom end. This further confirms downward movement of the stem **110** into the valve **50**. The expander mandrel **170** is no longer seen, as it has been urged below **line D-D**.

[00120] Finally, **Figure 6E** presents a cross-sectional view of the lockout tool **100** of **Figure 6A**, as shown through **line E-E** of **Figure 6A**. While the stem **110** and connected expander mandrel **170** have moved downward, the enlarged

outer diameter portion **176** of the expander mandrel **170** has not yet contacted the plurality of expander balls **105**. Thus, there is no change in the relative position of the expander balls **105** as compared to **Figure 3E**.

[00121] Moving now to **Figure 7A**, **Figure 7A** presents a cross-sectional view of the lockout tool **100** of **Figure 6A**. In this view, the lower stem **114** continues to be driven still further into the lockout tool **100**. This has enabled the carrier sleeve locking dogs **182** to clear an upper shoulder **116** of the stem extension member **114**. In addition, the locking dogs **184** remain in the recess **53** in the valve housing **52**.

[00122] **Figure 7B** provides a cross-sectional view of the lockout tool **100** of **Figure 7A**. Here, the view is taken across line B-B of **Figure 7A**. Again visible in this view are the three carrier sleeve locking dogs **182** carried by the carrier sleeve **180**. It can be seen that the carrier sleeve locking dogs **182** have been able to move inwardly due to the reduced outer diameter **116** and the slots **115** of the stem extension member **114**.

[00123] **Figure 7C** is a cross-sectional view of the lockout tool **100** of **Figure 7A**, taken across line C-C. Shown again in this view are the flow tube dogs **186** and locking dogs **184** radially disbursed around the stem extension member **114**. An enlarged outer diameter portion **117** of the stem extension **114** is adjacent both the flow tube dogs **186** and the locking dogs **184**, thereby urging these dogs **186**, **184** outwardly towards the valve housing **52** and into the recess **53**.

[00124] **Figure 7D** provides a cross-sectional view of the lockout tool **100** of **Figure 7A**, now taken across line D-D. Visible again in this view are carrier sleeve no-go dogs **188** carried by the carrier sleeve **180**. The stem extension member **114** within the carrier sleeve no-go dogs **188** is now a solid body, shown in cross-section. It should also be noted from **FIG. 7A** that the lower shoulder **119** of the stem extension **114** has now engaged the carrier sleeve no-go dogs **188**. As will be shown, as the stem **110** is urged further downward, the shoulder **119** will push the carrier sleeve no-go dogs **188** and attached carrier sleeve **180**

downward as well. This, in turn, pulls the flow tube dogs **186** downward, allowing the flow tube dogs **186** to drive the flow tube **54** downward.

[00125] Finally, **Figure 7E** shows a cross-sectional view of the lockout tool **100** of **Figure 7A**, taken across line **E-E** of **Figure 7A**. There is again no change in the relative position of the expander balls **105**, even as compared to **Figure 3E**.

[00126] The next step in the tool actuation process is shown in **Figure 8A**. **Figure 8A** presents the lockout tool **100** of **Figure 7A**, in cross-section. In this view, the stem **110** continues to be driven downward into the housing **120** for the lockout tool **100**. The flow tube dogs **186** have extended further downwardly and are above the flow tube **54** of the safety valve **50**. This will allow the flow tube dogs **186** to exert downward force against the flow tube **54**. The flow tube dogs **186** move downwardly within respective slots (seen at **153** in **FIG. 1**) in the upper housing **150**.

[00127] **Figure 8B** provides a cross-sectional view of the tool **100** of **Figure 8A**. Here, the view is taken across line **B-B** of **Figure 8A**. Three carrier sleeve locking dogs **182** are again visible along the carrier sleeve **180**. It is noted that the stem extension member **114** has been driven downward to the degree that the enlarged outer diameter portion **117** of the stem extension **114** has cleared the carrier sleeve locking dogs **182**. The diameter of the stem extension **114** is again reduced.

[00128] **Figure 8C** shows a cross-sectional view of the lock out tool **100** of **Figure 8A**, cut across line **C-C**. The flow tube dogs **186** and locking dogs **184** are again seen radially disposed about the carrier sleeve **180**. The flow tube dogs **186** are fully expanded outwardly against the inner diameter of the safety valve housing **52**, and are exerting downward force against the flow tube **54**.

[00129] **Figure 8D** gives a cross-sectional view of the lock out tool **100** of **Figure 8A**, shown through line **D-D** of **Figure 8A**. The carrier sleeve no-go dogs **188** are seen riding with the carrier sleeve **180**. The diameter of the stem extension **114** within the tool **100** is the same, as the enlarged outer diameter

portion **116** of the stem extension member **114** has not yet reached the level of the carrier sleeve no-go dogs **188**.

[00130] **Figure 8E** shows a cross-sectional view of the tool **100** of **Figure 8A**, taken across **line E-E**. There still remains no visible change in the relative position of the expander balls **105** as compared to **Figure 3E**.

[00131] The next step in the tool actuation process is seen in **Figure 9A**. **Figure 9A** presents yet another cross-sectional view of the lockout tool **100**. In this view, the stem **110** continues to be driven downward into the safety valve **50**. The carrier sleeve **180** and connected flow tube dogs **186** are shown driving the flow tube **54** downward towards the flapper **60**. The flow tube **54** is now visible around the ball housing **160**. Also, the shoulder **119** of the stem extension member **114** is driving the carrier sleeve no-go dogs **188** and connected carrier sleeve **180** further downward.

[00132] **Figure 9B** provides a cross-sectional view of the tool of **Figure 9A**, with the view being taken across **line B-B**. The carrier sleeve locking dogs **182** continue to ride along the carrier sleeve **180**. The carrier sleeve locking dogs **182** have moved downward adjacent to the locking dogs **184**. Thus, the locking dogs **184** are seen disposed adjacent the carrier sleeve locking dogs **182** around the carrier sleeve **180**.

[00133] **Figure 9C** shows a cross-sectional view of the lockout tool **100** of **Figure 9A**. Here, the view is shown across **line C-C**. The flow tube dogs **186** are fully expanded outwardly against the inner diameter of the safety valve housing **52**, and exert downward force against the flow tube **54** as described above. The flow tube **54** is now visible around the ball housing **160**.

[00134] **Figure 9D** demonstrates a cross-sectional view of the lockout tool **100** of **Figure 9A**. The cut is taken across **line D-D**. Visible in this view are carrier sleeve no-go dogs **188** disposed within the flapper valve housing **52**, and around the expander mandrel **170**. The carrier sleeve no-go dogs **188** continue to be driven downward by the stem **110**, including the stem extension member **114**.

[00135] **Figure 9E** is a cross-sectional view of the lockout tool **100** of **Figure 9A**, taken across **line E-E**. There remains no change in the relative position of the expander balls **105** as compared to **Figure 3E**. However, the flow tube **54** is now visible around the ball housing **160**.

[00136] **Figure 10A** presents the next step in the actuation process for the lockout tool **100** after the step of **Figure 9A**. **Figure 10A** provides a cross-sectional view of the tool **100**. In this view, the stem **110** has been driven further downward into the housing **52** for the safety valve **50**. The flow tube dogs **186** have now moved downward to the end of their stroke. In the arrangement of **FIG. 10A**, the flow tube dogs **186** and connected carrier sleeve **180** stroke out when the flow tube **54** reaches the end of its stroke. At this point, of course, the safety valve flapper **60** is completely opened. The lower shoulder **119** of the enlarged outer diameter portion **117** of the stem extension member **114** remains in contact with the carrier sleeve no-go dogs **188** so as to drive them downward. However, the carrier sleeve no-go dogs **188** are now aligned with a recess **57** in the upper housing **150**. As will be seen in **FIG. 11A**, this will allow the carrier sleeve no-go dogs **188** to move outwardly.

[00137] **Figure 10B** provides a cross-sectional view of the lockout tool of **Figure 10A**, taken across **line B-B**. The carrier sleeve locking dogs **182** continue to move downward through the safety valve housing **52** with the stem **110** and the carrier sleeve **180**.

[00138] **Figure 10C** shows a cross-sectional view of the tool **100**, with the view being taken through **line C-C** of **Figure 10A**. The flow tube dogs **186** remain visible, and remain fully expanded outwardly against the inner diameter of the safety valve housing **52**. The flow tube dogs **186** also remain shouldered out against the top of the upper housing **150**.

[00139] **Figure 10D** demonstrates a cross-sectional view of the lockout tool **100**, cut through **line D-D** of **Figure 10A**. The carrier sleeve no-go dogs **188**

continue to be driven downwardly by the shoulder **119** in the stem extension member **114**.

[00140] **Figure 10E** shows the lockout tool of **Figure 10A**, in cross-section. The view is taken across **line E-E**. There is again no change in the position of the expander balls **105** relative to the flow tube of the safety valve as compared to **Figure 3E**. The flow tube **54** remains visible circumferentially around the ball housing **160**, keeping the flapper member **60** in its fully open position.

[00141] The next step in the tool actuation process is seen in **Figure 11A**. **Figure 11A** presents yet another cross-sectional view of the lockout tool **100**. In this view, the stem **110** is still driving further downward into the safety valve **50**. The carrier sleeve no-go dogs **188** have been urged outwardly into the recess **57** in the upper housing **150**. This allows the stem extension member **114** to move downwardly within both the carrier sleeve **180** and the flow tube **54**. This, in turn, drives the expander mandrel **170** further downward. As noted, the expander mandrel **170** includes an enlarged diameter portion **176** that acts against the expander balls **105**. The enlarged diameter portion **176** can be seen now acting against the balls **105**, and driving them outwardly into the flow tube **54** of the safety valve **50**.

[00142] **Figure 11B** provides a cross-sectional view of the lockout tool **100** of **Figure 11A**, taken across **line B-B** of **Figure 11A**. The position of the carrier sleeve locking dogs **182** relative to the tool housing **120** has not changed from the view of **Figure 10B**.

[00143] **Figure 11C** shows the lockout tool **100** of **Figure 11A**, in cross-section. The view is taken across **line C-C**. There is also no change in the position of the flow tube dogs **186** relative to the tool housing **120**.

[00144] **Figure 11D** gives another cross-sectional view of the tool **100** of **Figure 11A**. Here, the view is taken across **line D-D**. The carrier sleeve no-go dogs **188**, which have popped outwardly into the recess **57** of the upper housing

150, are adjacent the enlarged diameter portion **117** of the stem extension member **114**.

[00145] Finally, **Figure 11E** provides a cross-sectional view through line **E-E**. The plurality of expander balls **105** are again seen. It can be seen that the diameter of the expander mandrel **170** has been enlarged relative to the diameter shown in previous "**E-E**" cross-section views. This causes the expander balls **105** to be expanded outward against the flow tube **54** of the safety valve **50**. In the arrangement of **Figure 11A**, the expander balls **105** have also begun to pinch the flow tube **54** into the non-moveable hard seat **58** of the safety valve **50**. This creates a profile in the hard seat **58** where it receives the flow tube **54**, thereby strengthening the frictional "lock" between the flow tube **54** and the seat **58**. This, in turn, maintains the flow tube **54** in its lowered position adjacent the flapper **60**. In this manner, the flapper **60** is locked in its open position.

[00146] **Figure 12A** presents a final cross-sectional view of the lockout tool **100**, and provides the final step in the lockout process. In this view, the expander mandrel **170** has been driven through the flapper **60** of the safety valve. A reduced inner diameter portion of the mandrel **170** has reached the depth of the expander balls **105** within the ball housing **160**. This has allowed the expander balls **105** to recess back within the ball housing **160**, and the flow tube dogs **186** to retract. This, in turn, allows the entire tool **100** to later be removed from the wellbore with tension placed in the slickline.

[00147] The stem extension member **114** has passed below the locking dogs **184** such that the top end of the stem extension **114** forms a shoulder below the locking dogs **184**. This allows the operator to pull the housing **120** and stem **110** of the tool **100** after the lockout process is completed.

[00148] **Figure 12B** is a cross-sectional view of the tool **100** of **Figure 12A**, taken across line **B-B**. The stem **110** has been moved through the tool housing **120** to the extent that the top end of the stem extension member **114** is adjacent the locking dogs **184**. The three locking dogs **182** are shown in **FIG. 12B**

disposed around the stem extension member **114**. The bottoms of the carrier sleeve locking dogs **182** are visible in this cut.

[00149] **Figure 12C** provides a cross-sectional view taken across **line C-C** of **Figure 12A**. It can be seen that the flow tube dogs **186** have cleared the enlarged diameter portion **117** of the stem extension member **114**, and are recessing inward.

[00150] **Figure 12D** shows the tool of **Figure 12A** in cross-section, with the view being taken across **line D-D**. The enlarged outer diameter portion **176** of the expander mandrel **170** has moved below the carrier sleeve no-go dogs **188**. The carrier sleeve no-go dogs **188** are again seen around the stem extension member's **114** diameter.

[00151] **Figure 12E** shows the lockout tool **100**, in cross-section, with the view being taken across **line E-E** of **Figure 12A**. The expander balls **105** have retracted and are no longer expanding the radial dimension of the flow tube **54**.

[00152] It can be seen that the expansion of the flow tube **54** of the safety valve **50** takes place radially. However, as best shown in the cross-sectional view of **Figure 11E**, the expansion is not completely circular. In the particular arrangement shown in **Figure 11E**, six expander balls **105** are used in order to contact the surrounding flow tube **54** and expand it outwardly against the seat **58**. In order to provide a more complete expansion, it is desirable to be able to rotate the ball housing **160** at least 60° in order to effectuate a completely circular expansion. Accordingly, an alternate embodiment of the present invention is provided which allows partial rotation of the ball housing **160** during the lockout tool actuation process.

[00153] **Figure 13** presents a section view of an alternate embodiment of the lockout tool **100** of the present invention. In this view, a grooved and spiraled spline **175** is placed around the expander mandrel **170** at the level of the enlarged outer diameter portion **176**. A bearing connection **165** is provided between the ball housing **160** and the lower end **154** of the upper housing **150**.

The allows the ball housing **160** to rotate. Downward force urged against the expander mandrel **170** causes the expander balls **105** to engage the grooved and spiraled spline **175**. This moves the balls outward into engagement with the inner diameter of the flow tube **54**. Further downward jarring causes not only initial deformation of the flow tube **54**, but also rotation of the ball housing **160** and expander balls **105**. Still further rotation and expansion results in a flow tube **54** diameter having an expanded circumferential band. This provides an even more secure frictional engagement of the flow tube **54** against the surrounding non-moveable hard seat **58** within the safety valve **50**.

[00154] As can be seen, an improved lockout tool for locking a subsurface safety valve in the open position has been provided. While certain embodiments of the lockout tool have been described and demonstrated herein, it is understood that this description is not intended to limit the scope of the invention, but that the actual scope of the invention is determined by the claims, which follow. Accordingly, other and further embodiments of the lockout tool may be provided that are within the spirit and scope of the present invention.

[00155] It is also understood that the lockout tool has utility outside of the context of safety valves. For example, the lockout tool may be inserted into any tubular member for which expansion is desired. For example, it may be desirable to expand a short section of tubing into frictional engagement with a surrounding string of casing in order to form a casing patch. In such an operation, the lockout tool would provide an initial expansion of the tubing section into frictional engagement with the surrounding casing. The lockout tool would then be removed from the wellbore, and a rotary expander tool would be inserted in its place. For a further discussion of the use of a rotary expander tool for installing a coiled tubing patch in another context, the reader is referred to U.S. Patent Application No. 10/106,178 entitled "Method for Installing an Expandable Coiled Tubing Patch." The named inventor therein is Hoffman.

[00156] The rotary expander tool (not shown) is lowered to a depth adjacent the tubing section (not shown). Thereafter, the expander tool is actuated in order

to further expand the tubing section into frictional engagement with the surrounding casing. The expander tool is further rotated and translated along a desired length within the wellbore in order to accomplish a complete expansion. In this manner, a tubing patch may be installed.

[00157] Other expansion applications are also contemplated within the present invention. In this regard, the tubing patch application represents only one such application. Again, the lockout tool may be employed to initially expand a portion of one tubular member into frictional engagement with another surrounding tubular member of any type.

[00158] It should also be noted that the lockout tool **100** of the present invention is not limited to a mechanically activated tool. The lockout tool **100** shown in **Figure 2** and the various step-drawings that follow is mechanically activated. In this respect, the stem **110** and connected expander mandrel **170** are urged downward through the SSV **50** using spang jars or other mechanical-force-delivering tool. However, the tool **100** can be quickly modified for hydraulic actuation.

[00159] **Figure 15** shows an alternate embodiment for the lockout tool **100** of **Figure 1**. In this embodiment, the lockout tool **100'** is hydraulically activated. The lockout tool **100'** is seen in a side, cross-sectional view. In order to effectuate a hydraulic activation, various seals are placed along the lockout tool **100'**. First, a seal **131** is placed along the outer diameter of the elongated housing **120**. This serves to seal the interface between the lockout tool **100'** and a run-in tool (not shown) connected with the working string (also not shown). In the arrangement of **Figure 15**, the seal **131** is disposed at the lower end of the no-go housing **130**.

[00160] Next, seals **111** are placed along the channel **143** between the outer diameter of the stem **110** and the inner diameter of the housing **120**. When the tool **100'** is in the run-in position of **Figure 15**, the seals **111** serve to prevent hydraulic fluid from passing into the interface between the stem **110** and the

housing 120. In the arrangement of **Figure 15**, one seal 111 is disposed within the top cap 142 to seal around the slidable upper stem 112, while another seal 111 is disposed around the upper stem 112 within the lock ring spacer 147.

[00161] The lockout tool 100' of **Figure 15** also includes a pressure relief groove 118. As will be described further below, the pressure relief groove 118 allows fluid to temporarily vent once the lockout tool 100' has been hydraulically actuated.

[00162] The modified lockout tool configuration of **Figure 15** is ideal for use in deviated wells where mechanical actuation of a lockout tool would be difficult. In operation, the upper stem 112 is connected to the lower end of a working string (not shown). For deviated wellbore operations, the working string is most likely a string of coiled tubing. A run-in tool is used that provides a seal between the inner diameter of the coiled tubing and the outer diameter of the housing 120. The lockout tool 100' is then run into the wellbore and landed into the housing of a safety valve (not shown in **Figure 15**).

[00163] Once the lockout tool 100' is landed into position, hydraulic fluid is pumped into the coiled tubing. As pressure increases within the sealed coiled tubing, the top of the upper stem 112 begins to act as a piston surface. The stem 112 and connected expander mandrel 170 are then urged downwardly within the SSV 50. As described above in connection with **Figures 3A** and **4A**, a temporary mechanical connection 140 is provided between the stem 110 and the no-go housing 130. Hydraulic pressure acting on the upper stem 112 will increase, ultimately causing the temporary connection 140 to break. The pressure relief groove 118 along the upper stem 112 will reach the upper cap 142, allowing hydraulic pressure to temporarily bleed. This informs the operator that the temporary mechanical connection 140 has been broken and the stem 110 and connected expander mandrel 170 are moving. The lockout tool 100' then progresses through the safety valve 50 as described above in connection with **Figures 5A-12A** in order to permanently open the flapper valve 60.

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[00164] It is also noted that a combination of mechanical and hydraulic force may be used to activate the lockout tool **100**. In this method, jars are used to break the temporary connection **140**. The coiled tubing is then pressured up in order to finish lockout. The pressure option may also be used to release a lockout tool **100** that has become stuck in a deviated wellbore during run-in.